MIXING UTILITY, LIQUID VISCOMETRIC APPARATUS

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STATEMENT REGARDING FEDERAL RIGHTS

This invention was made with government support under Contract No. W-7405-ENG-36 awarded by the U.S. Department of Energy. The government has certain rights in the invention.

FIELD OF THE INVENTION

The present invention relates generally to monitoring rheological parameters of liquid and plastic-solid samples during shear processing, and, more particularly, to process mixing of foam emulsions.

BACKGROUND OF THE INVENTION

Rheology is the study of the deformation and flow of matter, especially non-Newtonian flow of liquids and plastic flow of solids. Rheometers are instruments for determining flow properties of liquids and plastic flow of solids by measuring relationships between stress, strain, and time. Rheometers are used in various fields of application, including, but not limited to: food rheology, paints, concrete, cosmetics, biomedical materials, waste analysis, petroleum processing, plastics, rubbers, and adhesives.

The present invention comprises a type of rheometer that allows for the application of uniform shear in the generation of foam emulsions. Commercial systems are currently not available over the range of operating loads (0-40 lbf) typically encountered in the generation of foam emulsions. The present invention allows for the monitoring of the applied force in compression and/ or tension in real time over an operating range of 0-1000 lbf. The resulting data can then be directly translated to determine the evolution of the sample viscosity as a function of the process variables and formulation.

U.S. Patent No. 6,575,019, "Reciprocating Drive/ Pump System and Reciprocating Capillary Viscometer Utilizing Same", issued June 10, 2003, by David B. Larson, teaches a viscometer (rheometer) using a bi-directional dual

piston syringe pump assembly. Thus, there is one chamber and one piston. As the piston moves from one end of the chamber to the other, the processing fluid is displaced out of the chamber, through a long capillary tube, and back into the chamber on the other side of the piston. Instruments connected to the capillary tube detect rheological parameters.

There are differences between the viscometer taught in Larson, *supra*, and the present invention. Larson's viscometer relies on a pressure transducer arrangement to measure the pressure drop across the capillary. The present invention uses a load cell force measurement taken during the exchange of the sample volume between two syringe chambers connected by a capillary (syringe assembly) to determine viscosity.

Maintaining a stable sample temperature is important when determining rheological parameters. Larson indicates no ability to maintain temperature in the sample reservoirs, and, thus, the sample. However, the entire assembly of the present invention may be placed in an environmental chamber in order to maintain uniform temperature for all of the test material.

The capillary taught in Larson is designed for a single capillary of a certain length. The present invention allows for the use of interchangeable capillaries of differing cross-sectional sizes. Thus, different test material shear rates may be introduced and the resulting rheological measurements may be obtained.

Larson's viscometer does not denote the sample volume or the ability to adjust for different sized samples. The present invention is designed to accommodate syringe sizes from 10 cc to 50 cc, and can be easily modified to even larger syringe sizes.

Lastly, the viscometer taught in Larson requires significant maintenance between operations. For example, Larson's viscometer requires a flushing operation between processing different samples in order to clean out both ends of the piston chamber and the capillary tube. The design of the present invention allows for rapid removal and replacement of the syringe assembly (sample

container) without any cleaning required.

Various objects, advantages and novel features of the invention will be set forth in part in the description which follows, and in part will become apparent to those skilled in the art upon examination of the following or may be learned by practice of the invention. The objects and advantages of the invention may be realized and attained by means of the instrumentalities and combinations particularly pointed out in the appended claims.

SUMMARY OF THE INVENTION

In accordance with the purposes of the present invention, as embodied and broadly described herein, an apparatus for foam emulsion processing, and/ or determination of the rheological parameters of a given sample, includes a syringe assembly, a movable assembly, and a platform assembly. The syringe assembly has a first and second syringe connected by a capillary tube (emulsion needle). The movable assembly includes a holder tube within which the syringe assembly is secured. The platform assembly restrains movement of the movable assembly to only one axis.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in and form a part of the specification, illustrate the embodiments of the present invention and, together with the description, serve to explain the principles of the invention. In the drawings:

Figure 1 is a 3 pictorial illustration in partial cutaway of the present invention.

Figure 2 is a side view of the syringe assembly, movable assembly, and platform assembly of the present invention.

Figure 3 is a side view of the syringe assembly.

Figure 4 is a side view of the movable assembly.

Figure 5 is side view of the platform assembly.

Figure 6 is a cross-section of the present invention.

DETAILED DESCRIPTION

The present invention comprises an apparatus and method that determines rheological parameters of fluid samples and generates foam emulsions for use in various applications. One embodiment of the present invention uses two syringes connected by a capillary (emulsification needle) to perform these operations. Through this compact design the sample environment is fully contained. Sample chambers may be discarded after testing; therefore no cleaning of the apparatus is required.

Mechanical Design

Referring to Figure 1, one embodiment of the present invention comprises three main components: syringe assembly **1**, movable assembly **2**, and platform assembly **3**. Syringe assembly **1** is secured within movable assembly **2**. Movable assembly **2** moves in a reciprocating motion (back and forth) along directional axis **7, 8** within platform assembly **3.** Figure 3 illustrates syringe assembly **1**. Figure 4 illustrates movable assembly **2**. Figure 5 illustrates platform assembly **3**. Figure 6 is a cross sectional view illustrating how movable assembly **2** resides within platform assembly **3**.

Referring to Figures 2, 3, 4, and 5, determining the rheological parameters of a given sample is carried out by drawing the sample to be processed into either first syringe barrel **35** or second syringe barrel **15**. If foam emulsification is being performed, then a first fluid is drawn into first syringe barrel **35** and a second fluid is drawn into second syringe barrel **15**. Syringe assembly **1**, comprising a first and second syringe, is then assembled by connecting output port **45** of first syringe barrel **35** with output port **25** of second syringe barrel **15** through capillary tube **50** (also called an emulsion needle).

Syringe assembly **1** is then placed into movable assembly **2**. Movable assembly **2** includes holder tube **60** that defines first slot **66** and second slot **68**, which engage first flange **40** and second flange **20** of syringe assembly **1**,

respectively. Syringe assembly **1** is held within movable assembly **2** by a securing assembly comprising adjusting retainer nut **80**, spacer **65**, and spring **63**, thereby placing a downward force on, and securing first flange **40** within first slot **66**. Spacer **65** allows for the accommodation of different sized syringes.

Movable assembly **2** is held within platform assembly **3** by first pair of vee blocks **150**, **155** and second pair of vee blocks **160**, **165**, and, which are made of plastic (e.g. Teflon®) or any material exhibiting a low friction coefficient, such that holder tube **60** is constrained to move only along one directional axis **7**, **8** in a reciprocating motion. Second plunger **10** is manually manipulated into lower retainer coupling **137** and ball plunger screw **135** is tightened to secure second plunger **10** to base plate **130**. Adjustment means (e.g. screw) **90**, which is centered over first plunger **30**, is adjusted to center first plunger **30** and to prevent upward movement of first plunger **30** during operation.

Platform assembly **3** may be secured to a mount (not shown) at base plate **130**. Support members **110**, **120** structurally connect base plate **130** with T-cross member **100** and upper cross member **140**. Vee block **160** and Vee block **150** are attached to support member **120**, and Vee block **165** and Vee block **155** are attached to support member **110**. T-cross member **100** is one of the upper structural cross members of platform assembly **3** and is shaped to fit inside holder tube **60** (refer to Figure 6). T-cross member **100** includes adjustment means **90** that is axially aligned with lower retainer coupling **137** along directional axis **7**, **8**. Adjustment means **90** is centered over first plunger **30**, facilitating the centering of syringe assembly **1** within holder tube **60**. Upper cross member **140** provides structural stability to platform assembly **3**.

Large jam nut **70** mechanically holds attachment lug **75** onto the top of holder tube **60**. Attachment lug **75** may be attached to a load cell (not shown) that is provided with a means for providing reciprocating motion of movable assembly **2**. Any means that can provide reciprocating displacement of movable assembly **2** within platform assembly **3** sufficient to transfer the sample between first syringe

barrel **35** and second syringe barrel **15** is acceptable for purposes of operating embodiments of the present invention. In one embodiment, a computer controlled load frame is used as the reciprocating displacement means.

As the type and size of the load cell used, rate control of the reciprocating means, and orifice size are readily changeable, many operating ranges are possible.

Operation

When operation of the present invention is ready to begin, the reciprocating displacement means is placed into motion. Referring to Figure 2, during movement of movable assembly **2** in axial direction **7**, second plunger **10** is secured by lower retainer coupling **137** and does not move, but second syringe barrel **15** moves with holder tube **60**. The motion in axial direction **7** displaces second plunger **10** out of second syringe barrel **15**. During movement in axial direction **7**, first plunger **30** is prevented from moving by adjustment means **90**. Thus, first syringe barrel **35** is forced over first plunger **30**, causing plunger **30** to displace the sample down through capillary **50** into second syringe barrel **15**.

During movement in axial direction **8**, the process is reversed. Second plunger **10** pushes the sample out of second syringe barrel **15** through capillary **50** and back into first syringe barrel **35** as second syringe barrel **15** is pushed down over second plunger **10** by holder tube **60**. Note that first plunger **30** is displaced out of first syringe barrel **35** by the force of the sample being pushed out of second syringe barrel **15**. The process is repeated until the operation is completed.

Syringe assembly **1** is removed by loosening adjustment means **90**, ball plunger screw **135**, and retainer nut **80**. The processed sample can then be removed and a new syringe assembly placed into holder tube **60**.

Embodiments of the present invention may be placed in any spatial orientation, as the emulsification process and/ or rheological parameter determination is not affected by gravity or spatial orientation. Thus, directional

axis **7**, **8** may be horizontal, vertical, or any angle in-between horizontal and vertical.

Rheological measurements, including kinematic and dynamic viscosity, shear rate, velocity through capillary, and wall stress of the sample, are determined by knowing the applied force (as given by an attached load cell) and calculating for a fixed volume that passes through a known orifice (capillary tube) at a controlled rate.

The applied force measurement, used in the calculation of the above rheological measurements, is obtained by subtracting the amount of force required to move movable assembly **2** when the sample is not present from that force required to move assembly **2** when the sample is present. Hence, embodiments of the present invention do not use probes (transducers) in direct contact with the sample for measurement.

If the present invention is used as a foam emulsifier, the foam emulsification process of a sample comprising two fluids is considered complete when monitoring indicates that the sample exhibits the desired rheological parameters.

The foregoing description of the invention has been presented for purposes of illustration and description and is not intended to be exhaustive or to limit the invention to the precise form disclosed, and obviously many modifications and variations are possible in light of the above teaching.

The embodiments were chosen and described in order to best explain the principles of the invention and its practical application to thereby enable others skilled in the art to best utilize the invention in various embodiments and with various modifications as are suited to the particular use contemplated. It is intended that the scope of the invention be defined by the claims appended hereto.